REMARKS

Telephone Conference With Examiner

In a telephone conference on October 13, 2004 Applicants' representative, Cynthia J. Lee, confirmed the election of the species. In accordance with the numbering of the Response submitted by Applicants on September 10, 2004, the election is as follows:

B.1 as a positive tone sacrificial material,

2 and 4 as a polypropylene carbonate,

3 as tetrakis(pentafluorophenyl)borate-4-methylphenyl[4-(1-methyl)phenyl]iodonium, and

5 not in the elected invention.

Cancellation of Claim 9

Claim 9 is canceled without prejudice, waiver, or disclaimer. Applicants take this action merely to reduce the number of disputed issues and to facilitate early allowance and issuance of other claims in the present application. Applicants reserve the right to pursue the subject matter of these canceled claims in a continuing application, if Applicants so choose, and do not intend to dedicate any of the canceled subject matter to the public.

Response To Rejections

Response To Claim Rejection Under 35 U.S.C. §112, Second Paragraph

Claim 12 was rejected because it contains the trademark "Rhodosil™." The Office Action states, "[w]here a trademark or trade name is used in a claim as a limitation to identify or describe a particular material or product, the claim does not comply with the requirements of 35 USC 112, second paragraph." *Office Action* at 2. Applicants have deleted the claim term "Rhodosil™ Photoinitiator 2074 (FABA)." Applicants wish to note that the Rhodosil™ (sic, "Rhodorsil") element was already claimed in the list of possible photoacid generators, as the first item in claim 12, namely DPI-TPFPB. Thus, Applicants assert that prosecution history does not apply with respect to the Rhodosil™ photoacid generator, as this photoacid generator remains in claim 12.

Applicants further wish to clarify that the foregoing amendment has been made for purposes of better defining the composition in response to the rejections made under 35 U.S.C. § 112, and not in response to the rejections made based on prior art. Indeed, Applicants submit that no substantive limitations have been added to the claims. Therefore, no prosecution history estoppel arises from this amendment. *Black & Decker, Inc. v. Hoover Svc. Ctr.*, 886 F.2d 1285, 1294 n. 13 (Fed. Cir. 1989); *Andrew Corp. v. Gabriel Elects., Inc.*, 847 F.2d 819 (Fed. Cir. 1988); *Hi-Life Prods. Inc. v. Am. Nat'l. Water-Mattress Corp.*, 842 F.2d 323, 325 (Fed. Cir. 1988); *Mannesmann Demag Corp. v. Eng'd. Metal Prods. Co., Inc.*, 793 F.2d 1279, 1284-1285 (Fed. Cir. 1986); *Moeller v. Ionetics, Inc.*, 794 F.2d 653 (Fed. Cir. 1986).

<u>Response To Claim Rejections Under 35 U.S.C. §103</u>

(a) Claims 1-7, 9, and 11-13 stand rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over *Narang et al.* (Reference "O" as submitted) by Applicants. Claim 9 has been canceled without prejudice, waiver, or disclaimer. Thus, the rejection of this claim is moot.

Specifically, the Office Action states as follows:

> *Narang et al.* disclose, teach and suggest a composition comprising (1) polycarbonate being read within the broadly claimed polymer and (2) from 2% of diaryliodonium salts being read within the broadly claimed photoacid generator. The claims contain the properties of the material. They are reasonably considered as being inherent in the absence of convincing evidence to the contrary. Please especially see under "RESULTS AND DISCUSSION". Since *Narang et al.* disclose, teach and suggest the requisite chemical ingredients of the claimed composition, it is reasonable that the claims would have the same or about the same properties as claimed. The law required that applicants show or provided convincing evidence to the contrary to speed up the prosecution and to avoid any later work for an inherency of the claimed properties since a claim would has no value if one later show or provide them from a pieces of a reference as clearly pointed out and set forth in paragraph "V" above because an argument alone may have and be given a little to no value.

Office Action at 5. Applicants respectfully traverse for at least the following reasons.

Independent claim 1 as amended recites the following:

> 1. A ***sacrificial composition of matter that decomposes to form air-regions***, the sacrificial composition comprising:
>
> a sacrificial polymer that undergoes acid-catalyzed decomposition, wherein the sacrificial polymer is chosen from ***polypropylene carbonate (PPC), polyethylene carbonate (PEC), polycyclohexane carbonate (PCC), polycyclohexanepropylene carbonate (PCPC), polynorbornene carbonate (PNC), a copolymer of polynorbornene and polynorbornene carbonate, and combinations thereof***; and
>
> a catalytic amount of a photoacid generator, wherein the photoacid generator is chosen from a nucleophilic halogenide, a complex metal halide anion, and combinations thereof.

Claim 1, amended (emphasis added).

It is a well established law that, for a proper rejection of a claim under 35 U.S.C. §103 as being obvious based upon a single reference, the reference must disclose, teach, or suggest, either implicitly or explicitly, all elements/features of the claim at issue. *See, e.g., In Re Dow Chemical*, 5 U.S.P.Q.2d 1529, 1531 (Fed. Cir. 1988), and *In re Keller*, 208 U.S.P.Q.2d 871, 881 (C.C.P.A. 1981). Independent claim 1 is allowable for at least the reason that *Narang et al.* do not disclose, teach, or suggest the features that are highlighted in claim 1 above. More specifically, *Narang et al.* do not teach or suggest at least the following: a sacrificial composition that decomposes to form air-regions, and a sacrificial composition that includes a sacrificial polymer that is chosen from polypropylene carbonate (PPC), polyethylene carbonate (PEC), polycyclohexane carbonate (PCC), polycyclohexanepropylene carbonate (PCPC), polynorbornene carbonate (PNC), a copolymer of polynorbornene and polynorbornene carbonate, and combinations thereof.

The feature of a "sacrificial composition that decomposes to form air-regions" as recited in the preamble of claim 1 is not taught or suggested by *Narang et al.* Instead, *Narang et al.* teach "positive photoresists" that are formed during decomposition of its disclosed composition, not air-regions as recited in claim 1. *See Narang et al.* at "Introduction." Additionally, *Narang et al.* teach that their polycarbonates decompose "to the corresponding diene and the bisphenol" and that "[t]he post baked films were developed with butan-1-ol to yield positive tone images." *Id* at "Results and Discussion." Because there is a <u>left-over solid residue</u> after the decomposition of the polycarbonates of *Narang et al.* (*i.e.*, the diene and the bisphenol), the composition of

Narang et al. is not a "sacrificial composition that decomposes to form air-regions", as recited in claim 1. Instead, the diene and the bisphenol of *Narang et al.* must be washed with an alcohol to dissolve and wash away the residue, unlike the composition of claim 1. The instant specification makes it clear that:

> [f]or embodiments using the sacrificial composition to create air-regions having three-dimensional structures, the <u>decomposition of the sacrificial composition should produce gas molecules small enough to permeate one or more of the materials surrounding the sacrificial composition</u> (*e.g.*, an overcoat layer). In addition, the sacrificial composition preferably decomposes slowly, so as not to create undue pressure build-up while forming the air-region within the surrounding materials.

Specification at page 6, lines 24-31 (emphasis added). Thus, because the sacrificial composition of claim 1 decomposes to form air-regions, and the photoresists of *Narang et al.* do not, the composition of claim 1 is inherently nonobvious over *Narang et al.* Applicants therefore respectfully request that the rejection of this claim be withdrawn for at least this reason.

Additionally, *Narang et al.* do not teach or suggest the polycarbonates that are recited in amended claim 1. Instead, <u>*Narang et al.* teach only tertiary diol polycarbonates</u>. *See id.*, throughout. The polycarbonates recited in claim 1 are <u>not</u> tertiary diol polycarbonates. Applicants wish to note that claim 1 as amended specifically recites the elected species of the sacrificial polymer, *i.e.*, polypropylene carbonate.

A claim cannot be deemed obvious in view of a reference if the reference "teaches away" from the claim. *See In re Gurley,* 2 F.3d 551, 31 USPQ2d 1130, 1131 (Fed Cir. 1994). Specifically, "<u>[a] reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference</u>, or would be led in a direction divergent from the path that was taken by the applicant...." *Id.* (emphasis added). *Narang et al.* clearly teach away from using any polycarbonate other than a tertiary diol polycarbonate.

Narang et al. teach that "[a] variety of polycarbonates incorporating tertiary diols were synthesized." *Id.* at "Results and Discussion", 1st paragraph. Additionally, they note the following:

> The <u>sensitivity of the resists is dependent upon the structure of the tertiary diols</u> and the onium salts. <u>Tertiary diols containing α-phenyl groups provided higher sensitivity</u>.

Id. (emphasis added). Indeed, the title of *Narang et al.'s* reference is "Chemical Amplification in t-Diol Polycarbonate Resists." By teaching the necessity of the tertiary diol and that the α-phenyl groups provided higher sensitivity, *Narang et al.* teach away from the polycarbonates of claim 1 that are not tertiary diols, and that do not have an α-phenyl group. One skilled in the art, upon reading the disclosure of *Narang et al.*, that requires a tertiary diol in the polycarbonate, and emphasizes the increased sensitivity of the α-phenyl groups, would be discouraged from using polycarbonates that instead have an <u>α-H</u>, as the polycarbonates of claim 1.

Indeed, the inventors have discovered that the bisphenol leaving group of *Narang et al.* leaves behind a residue that is difficult to remove. By using polycarbonates with an α-H in the sacrificial composition of claim 1 (which is taught against by *Narang et al.*), the inventors discovered that decomposition of the sacrificial composition is inherently autocatalytic, *i.e.*, only a small amount of photoacid generator is needed to decompose the sacrificial composition because the decomposition then uses the free proton to catalyze the decomposition of the next polymer. The reaction proceeds at a faster rate, is more complete, and does not leave a solid residue, all of which are surprising advantages over the polycarbonates taught by *Narang et al.* Consequently, *Narang et al.* does not render claim 1 obvious, and the rejection should be withdrawn over all recited sacrificial polymers, including the elected species, *i.e.*, polypropylene carbonate.

Because independent claim 1 is allowable over the prior art of record, its dependent claims 2-7 and 11-13 are allowable as a matter of law, for at least the reason that these dependent claims contain all features/elements of their independent claim 1. *Minnesota Mining and Mfg.Co. v. Chemque, Inc.*, 303 F.3d 1294, 1299 (Fed. Cir. 2002).

Additionally and notwithstanding the foregoing allowability of these dependent claims, the dependent claims recite further features and/or combinations of features (as is apparent by examination of the claims themselves) that are patentably distinct from the prior art of record. Hence, there are other reasons why these dependent claims are allowable. For example, dependent claim 3 recites "wherein the composition decomposes at a temperature range from about 175 to 200

°C." *Narang et al.* disclose that their films were baked at "120 ± 5 °C" and that "[t]he baking process results in the ... thermal decomposition of the polycarbonate...." Thus, the temperature range of claim 3 is well outside the temperature range that is taught or suggested by *Narang et al.* Applicants therefore respectfully request that the rejection of this claim be withdrawn for this reason as well.

(b) Claims 1-7, 9, and 11-13 with respect to the applied species are rejected under 35 US C. 103(a) as being unpatentable over *Hsieh et al.* (U.S. Patent No. 5,587,224). Claim 9 has been canceled without prejudice, waiver, or disclaimer. Thus, the rejection of this claim is moot.

Specifically, the Office Action states the following:

> *Hsieh et al.* disclose, teach and suggest a composition comprising (1) polycarbonate being read within the broadly claimed polymer and (2) photoacid generator being read within the broad claims. Please The claims contain the properties of the material. They are reasonably considered as being inherent in the absence of convincing evidence to the contrary. Please see the whole disclosure or the applied reference, especially at col 24:41-43, 25:20-22, Example V, Table 1 Sample Nos. 1, 4, 5, 6, 7, 8, and 9; Example VI, Table 2 Sample No 10. Since *Narang et al.* [sic] disclose, teach and suggest the requisite chemical ingredients of the claimed composition, it is reasonable that the claims would have the same or about the same properties as claimed. The law required that applicants show or provided convincing evidence to the contrary to speed up the prosecution and to avoid any later work for an inherency of the claimed properties since a claim would has no value if one later show or provide them from a pieces of a reference as clearly pointed out and set forth in paragraph "V" above because an argument alone may have and be given a little to no value.

Office Action at 5. Applicants respectfully traverse. Independent claim 1 is allowable for at least the reason that *Hsieh et al.* do not disclose, teach, or suggest the features that are highlighted in claim 1 above on page 9 of this Response. More specifically, *Hsieh et al.* do not teach or suggest at least the following: a sacrificial composition that decomposes to form air-regions, and a sacrificial composition that includes a sacrificial polymer that is chosen from polypropylene carbonate (PPC), polyethylene carbonate (PEC), polycyclohexane carbonate (PCC), polycyclohexanepropylene carbonate (PCPC), polynorbornene carbonate (PNC), a copolymer of polynorbornene and polynorbornene carbonate, and combinations thereof.

The feature of a "sacrificial composition that decomposes to form air-regions" as recited in the preamble of claim 1 is not taught or suggested by *Hsieh et al.* Instead, *Hsieh et al.* teach "a coating...comprised of a photolysis reaction product of a charge transporting polymer and a photoacid compound" and "overcoatings ... [that] generally comprise least [sic] two constituents: a charge transporting polymer; and a photo lablie or photon dissociable onium salt dopant also referred to as a photoacid." *Hsieh et al.* at col. 5, lines 62-65 and col. 7, lines 11-15. Because *Hsieh et al.* teach a coating, or overcoating, that remains on the disclosed donor roll, the composition of *Hsieh et al.* is not a "sacrificial composition that decomposes to form air-regions", as recited in claim 1. Indeed, the compositions of *Hsieh et al.* are not sacrificial at all.

The Office may assert that *Hsieh et al.* may be modified to act as a sacrificial composition. It should be noted, though, that "[t]he mere fact that the prior art could be so modified would not have made the modification obvious unless the prior art suggested the desirability of the modification." *In re Gordon*, 733 F.2d 900, 221 U.S.P.Q. 1125, 1127 (Fed. Cir. 1984). In *Hsieh et al.* there is no suggestion in the reference itself of the desirability of modifying their composition in a manner consistent with the composition of claim 1. *Hsieh et al.* instead teaches away from the sacrificial nature of the composition of claim 1 because if the composition of *Hsieh et al.* was sacrificial (*i.e.*, decomposed to form air-regions), then it would not to be a coating or overcoating. Thus, for at least this reason, claim 1 is nonobvious in view of *Hsieh et al.* Applicants therefore respectfully request that the rejection of this claim be withdrawn for at least this reason.

Additionally, *Hsieh et al.* do not teach or suggest the polycarbonates that are recited in amended claim 1. Instead, *Hsieh et al.* teach only aromatic polycarbonates. *See id.* at col. 25, lines 20-22, throughout. Specifically, *Hsieh et al.* teach Makrolon®, Apec®, Merlon®, and Lexan® as the possible polycarbonates. Each of these polycarbonates are trademarks for aromatic polycarbonates. *See* Exhibit "A", attached hereto. The polycarbonates recited in claim 1 are not aromatic polycarbonates.

Again, the inventors have discovered that the bisphenol leaving group of each of the polycarbonates of *Hsieh et al.* leaves behind a residue that is difficult to remove. By using polycarbonates with an α-H in the sacrificial composition of claim 1, the inventors discovered that decomposition of the sacrificial composition is inherently autocatalytic. Because the composition of *Hsieh et al.* is used as a coating and not a sacrificial matter as claim 1, there is no

need by *Hsieh et al.* to use polycarbonates that would decompose at the rate of those of claim 1. Thus, the carbonates of claim 1 are nonobvious over the polycarbonates disclosed in *Hsieh et al.* Consequently, the combination of *Hsieh et al.* does not render claim 1 obvious, and the rejection should be withdrawn.

Because independent claim 1 is allowable over the prior art of record, its dependent claims 2-7 and 11-13 are allowable as a matter of law, for at least the reason that these dependent claims contain all features/elements of their independent claim 1. Additionally and notwithstanding the foregoing allowability of these dependent claims, the dependent claims recite further features and/or combinations of features (as is apparent by examination of the claims themselves) that are patentably distinct from the prior art of record. Hence, there are other reasons why these dependent claims are allowable. For example, dependent claim 7 recites "wherein the composition is a positive tone sacrificial material." As noted above, *Hsieh et al.* do not teach or suggest a sacrificial material at all, and certainly not a positive tone sacrificial material. Thus, claim 7 is not taught or suggested by *Hsieh et al.* Applicants therefore respectfully request that the rejection of this claim be withdrawn for this reason as well.

CONCLUSION

In light of the foregoing amendments and for at least the reasons set forth above, Applicants respectfully submit that all rejections have been traversed, rendered moot, and/or accommodated, and that the now pending claims 1-7 and 11-31 are in condition for allowance. Favorable reconsideration and allowance of the present application and all pending claims are hereby courteously requested. If, in the opinion of the Examiner, a telephone conference would expedite the examination of this matter, the Examiner is invited to call the undersigned agent at (770) 933-9500.

Respectfully submitted,

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Resources

Baytown Manufacture and Delivery of aromatic amines, aromatic isocyanates, aliphatic isocyanates, inorganic base materials (chlorine, liquid caustic soda, hydrochloric acid), [redacted]

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EXHIBIT A
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Bayer MaterialScience

Product Information

APEC® High-Heat Polycarbonate Resin

1600 (General-Purpose Grade)
1700 (General-Purpose Grade)/**1703** (UV-Stabilized Grade)
1800 (General-Purpose Grade)/**1803** (UV-Stabilized Grade)

Description

Apec high-heat polycarbonate is an amorphous, naturally transparent thermoplastic for processing by injection molding or extrusion. [redacted] which extend the service range of standard polycarbonate towards higher temperatures. All Apec resins offer an excellent combination of high heat resistance, clarity, and processibility.

Different series have been engineered to precisely match individual heat requirements. These series are distinguished by their deflection temperature under load (DTUL at 264 psi), which ranges from 284°F (140°C) for the Apec 1600 series to 324°F (162°C) for the Apec 1800 series. Within each series, there are formulations with standard performance additives. For example, Apec 1705 is the release grade in the 1700 series, and Apec 1803 is the UV-stabilized grade in the 1800 series.

Apec resins are available in natural clear, clear tint, and transparent as well as opaque colors.

Applications

With their unique combination of high heat resistance and inherent clarity, Apec resins are used in a variety of demanding transparent and opaque applications. Automotive applications include lenses, headlight and brakelight reflectors, and turn signal bulb covers. Other applications include lenses for industrial lighting, lamp housings, hair dryer diffusers, contact lens containers, and microwave oven doors. As with any product, use of Apec resin in a given application must be tested (including but not limited to field testing) in advance by the user to determine suitability.

For medical-device applications requiring biocompatibility and sterilization at high temperatures, Apec 1745 resin can be considered. For further information on this medical grade, please request a product information bulletin from your Bayer MaterialScience representative.

General Characteristics of Apec High-Heat Polycarbonate

Hydrolytic Stability. Parts molded from polycarbonate absorb only about 0.15% water at room temperature and 50% relative humidity. Dimensional stability and mechanical properties remain virtually unaffected. Even with immersion in water, dimensional changes measure only about 0.5%. Although frequent, intermittent contact with hot water does not harm polycarbonate, continuous exposure to humidity or water at high temperatures (>140°F/60°C) is not recommended due to hydrolytic degradation, which reduces impact and tensile properties.

Chemical Resistance. The behavior of Apec high-heat polycarbonate in contact with chemicals is similar to that of standard polycarbonate. Apec resins are resistant to mineral acids, a large number of organic acids, many oxidizing and reducing agents, neutral and acidic saline solutions, some greases and oils, saturated aliphatic and cycloaliphatic hydrocarbons, and most alcohols. It is important to note that Apec polycarbonate is degraded by alkaline solutions, ammonia gas and its solutions, and amines. Apec polycarbonate dissolves in a number of organic solvents, such as halogenated hydrocarbons and specific non-halogenated solvents such as toluene, ethylacetate, methyl acetate, methyl ethyl ketone and tetrahydrofuran. The solubility of Apec resins is grade-dependant. Special high purity solubility grades are available for solution applications. Other organic compounds cause polycarbonate to swell or stress-crack, e.g., acetone. Since chemical resistance to various media is dependent on variables, such as concentration, time, temperature, part design, and residual stresses, the above information should serve only as a guideline. It is imperative that production parts be evaluated under actual applications prior to commercial use.

EXHIBIT A
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This Article's Table of Contents

industrial polymers, major

Encyclopædia Britannica Article

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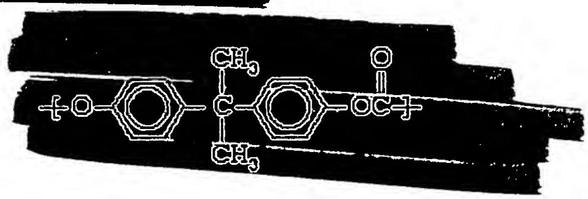
Heterochain polymers > Polyesters > Polycarbonate (PC)

Marketed under the trademarked names Lexan and Merlon, among others, PC is a special type of polyester used as an engineering plastic. It has exceptional stiffness, mainly by virtue of having more aromatic rings incorporated into the polyester chain:



This structure is arrived at by reacting bisphenol A, an aromatic derivative of benzene, with **phosgene**, a highly reactive...

industrial polymers, major... *(75 of 14540 words)*

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EXHIBIT A
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GE Research &
Development Center

Polycarbonates

D.J. Brunelle and G. Kailasam

2001CRD136, February 2002
Class 1

Technical Information Series

EXHIBIT A
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Corporate Research and Development

Technical Report Abstract Page

Title Polycarbonates

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Component Polymer and Specialty Chemical Technologies

Report Number 2001CRD136

Date February 2002

Number of Page 32

Class 1

Key Words Polycarbonate, review, manufacture, phosgene, bisphenol A, BPA, diphenyl carbonate, polymer properties

Polycarbonates are an unusual and extremely useful class of high heat polymers known for their toughness and clarity. The vast majority of polycarbonates are based on bisphenol A (BPA), and sold under the trade names Lexan® (GE), Makrolon® (Bayer), Caliber® (Dow), Panlite® (Teijin) and Iupilon® (Mitsubishi). BPA polycarbonates have glass transition temperatures (T_g) in the range of 140-155°C, and are widely regarded for their optical clarity and exceptional impact resistance and ductility at or below room temperature. Other properties, such as modulus, dielectric strength, and tensile strength are comparable to other amorphous thermoplastics at similar temperatures below their respective T_g's. However, whereas most amorphous polymers are stiff and brittle below their T_g's, polycarbonates retain their ductility. Polycarbonates are prepared commercially by two completely different processes: Schotten-Baumann reaction of phosgene and an aromatic diol in an amine-catalyzed interfacial condensation reaction, or via base-catalyzed transesterification of a bisphenol with a monomeric carbonate such as diphenyl carbonate. Each process has its own inherent advantages and disadvantages. Many important products are also based on polycarbonate in blends with other materials, copolymers, branched resins, flame-retardant compositions, foams, and other materials. Polycarbonates are produced with global manufacture currently just over 2 million tons annually. Polycarbonate is also the object of both industrial and academic research, due to its widespread utility and unusual properties. Research on polycarbonates has steadily increased over the past two decades, with with over 5000 publications on the topic since 1995, and nearly 20,000 patents having appeared globally, more than 8000 since 1995. Polycarbonate has been the subject of three monographs, once of them published in 2000. This paper gives a brief overview of polycarbonate.

Manuscript received Augusst 15, 2001

*GE Plastics

EXHIBIT A
PAGE 6 OF 10

Polycarbonates

D.J. Brunelle and G. Kailasam

Polycarbonates are an unusual and extremely useful class of high heat polymers known for their toughness and clarity. The vast majority of polycarbonates are based on bisphenol A (BPA), and sold under the trade names Lexan® (GE), Makrolon® (Bayer), Caliber® (Dow), Panlite® (Teijin) and Iupilon® (Mitsubishi). Many other producers and suppliers are available. BPA polycarbonates have glass transition temperatures (T_g) in the range of 140-155°C, and are widely regarded for their optical clarity and exceptional impact resistance and ductility at or below room temperature. Other properties, such as modulus, dielectric strength, and tensile strength are comparable to other amorphous thermoplastics at similar temperatures below their respective T_g's. However, whereas most amorphous polymers are stiff and brittle below their T_g's, polycarbonates retain their ductility. Polycarbonates are prepared commercially by two completely different processes: Schotten-Baumann reaction of phosgene and an aromatic diol in an amine-catalyzed interfacial condensation reaction, or via base-catalyzed transesterification of a bisphenol with a monomeric carbonate such as diphenyl carbonate. Each process has its own inherent advantages and disadvantages. Many important products are also based on polycarbonate in blends with other materials, copolymers, branched resins, flame-retardant compositions, foams, and other materials. Polycarbonates are produced by more than a dozen companies, with global manufacture currently just over 2 million tons annually. Polycarbonate is also the object of both industrial and academic research, due to its widespread utility and unusual properties. Research on polycarbonates has steadily increased over the past two decades, with with over 5000 publications on the topic since 1995, and nearly 20,000 patents having appeared globally, more than 8000 since 1995. Japanese companies lead the number of patent holders, including Teijin Chemicals, Teijin Limited, Sekisui Chemical, Asahi Chemical, Idemitsu Petrochemical, Toray Ind., and Mitsubishi Gas Chemical Company. Other companies with significant patent portfolios include General Electric, Bayer AG, and Dow Chemical. Polycarbonate has been the subject of three monographs, once of them published in 2000.[1]

Historical Development

The first polycarbonates were prepared by Einhorn in the late 1890s via reaction of hydroquinone or resorcinol with phosgene using pyridine as solvent.[2] Attempts to prepare the polycarbonate of catechol led only to the cyclic five-membered carbonate. A few years later, the same materials were prepared by Bischoff via solventless transesterification using diphenyl carbonate.[3] The hydroquinone polymer is brittle, crystalline, insoluble in most solvents, and melted at > 280°C. The polymer from resorcinol is glassy and brittle, although it crystallizes from solution, and melts at about 190-200°C. Both of these polymers were apparently of low molecular weight and owing to difficulties of processing and characterization, were not developed further. In fact, no research on polycarbonates appeared in the literature for about 30 years after their initial dis

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covery. In the early 1930s, the preparation of *aliphatic* carbonates was studied during the investigation of the preparation and properties of polyesters by Carothers, et al.[4] Because the reactions of aliphatic alcohols and phosgene proceed more slowly than those of phenols, two other methods were used to prepare the aliphatic polycarbonates: direct transesterification reactions, and ring-opening polymerization of low molecular weight cyclic polycarbonates prepared by a distillative transesterification-depolymerization. Further work was carried out in the 1940s. 1,6-Hexanediol polycarbonates were prepared via transesterification using dibutyl carbonate.[5] The aliphatic polycarbonates had low melting points and did not prove interesting commercially. In 1941, the Pittsburgh Plate Glass Company (PPG) introduced a liquid casting resin designated as CR-39.[6] This material, formally a polycarbonate, was a cross-linked thermoset resin prepared by a peroxide-initiated radical polymerization of the bisallyl carbonate of diethylene glycol. The starting material was prepared from allyl alcohol and diethylene glycol bischloroformate (eq. 1). Once polymerized, CR-39 was a colorless, transparent, scratch-resistant plastic which was used in optical applications. These materials differ markedly from the current thermoplastic polycarbonates. Although its nature and chemical makeup are completely different from modern polycarbonates, CR-39 was the first commercially available polycarbonate.

A reexamination of aromatic polycarbonate chemistry was carried out about 50 years after the first polycarbonates of resorcinol and hydroquinone were discovered. In independent investigations by Schnell at Bayer AG and by Fox at General Electric, it was discovered that the polycarbonates of BPA could be prepared (eq. 2). Unlike the aliphatic polycarbonates prepared earlier, which were either liquids or low melting solids, the aromatic polycarbonates were tough, amorphous solids having elevated glass-transition temperatures. Owing to the unusual properties of the BPA polycarbonate, ie, toughness, transparency, and thermal stability, each company began development programs. Bayer AG, the first to report the properties of a series of polycarbonates,[7] had patents issuing as early as 1954.[8] Commercial production of polycarbonate by Bayer AG began in Germany in 1958, and in the United States in 1960. General Electric (GE) started U.S. commercial production in 1960. After a period of litigation, U.S. patents were issued to Bayer AG, which claimed an interfacial process for preparation of polycarbonates, and had multiple claims to various polycarbonates.[9] The basic GE patent claimed the transesterification process and the polycarbonate product so formed.[10] Since that time extensive research has been carried out on polycarbonates. Several manufacturers have developed many niches of new products, blends, or processes for production of these materials. Although GE and Bayer AG remain the principal producers, at least 50 companies have patented some aspect of polycarbonate chemistry. Over a dozen producers exist worldwide.

In addition, Bayer's polymers are used in a wide variety of other applications, including handles on surgical equipment, contact-lens cases, diagnostic reaction cells and sterilizable laboratory animal breeding cages. Only Bayer resins designated as "medical-grade" may be considered as candidates for applications requiring biocompatibility

Engineering Polymer Product Families

- Makrolon® polycarbonate resins provide excellent impact strength, glass-like transparency, excellent temperature resistance, superior processability and dimensional stability. Certain Makrolon resins designated as "medical-grade" meet FDA-modified ISO 10993-I requirements (see "Biocompatibility"). Makrolon polycarbonate resins can be sterilized using a broad range of sterilization techniques including EtO, steam and gamma or E-beam radiation (see "Sterilization").

- Apec® high-heat polycarbonate resins extend the service range of Makrolon polycarbonate resins to higher temperatures. These resins provide an excellent combination of high-heat resistance, clarity, toughness and processability. Certain Apec resins designated as "medical-grade" meet FDA-modified ISO 10993-I requirements (see "Biocompatibility"). Apec resins can be used in applications subjected to repeated autoclave (saturated steam) sterilization, especially at higher sterilization temperatures (see "Sterilization").

- Lustran® ABS (acrylonitrile-butadiene-styrene) and SAN (styrene acrylonitrile) resins provide an excellent balance of properties for molded medical parts. Lustran ABS 348-1002 natural, 2002 sno-white and other selected colors meet FDA-modified ISO 10993-I requirements (see "Biocompatibility"). SAN resins can exhibit "water clear" optical clarity. Several Lustran SAN resins for the medical market comply with USP 23 Class VI. Both Lustran ABS and SAN resins offer excellent chemical resistance and are sterilizable by EtO or gamma (see "Sterilization").

- Bayblend® polycarbonate/ABS blends provide good toughness and impact resistance even at low temperatures, excellent color stability and consistency, easy processing, dimensional and thermal stability and excellent creep resistance. Flame-retardant (FR) grades are available which use advanced FR technology that is antimony/bromine/chlorine-free. They also provide good thin-wall design capability and are easily plateable or EMI-shielded. These resins have not been tested for biocompatibility.

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compounding facility in Newark, Ohio. Other Division operations include Wolff Walsrode in Burr Ridge, Ill., and Deerfield Urethane Inc., in Whately, Mass. Sales offices are located in Irvine, Calif.; Rosemont, Ill.; and Woodbridge, N.J.

The Plastics Division is an essential element of Bayer Corporation's Automotive Products Center (APC) in Auburn Hills, Mich. The APC is the marketing and technological support hub for automotive applications of all Bayer products, including engineering plastics, polyurethanes, coatings and rubber. Bayer Corporation also has two Polymers Research Centers, located in Pittsburgh and New Martinsville, that develop new technologies to support the Plastics Division and leverage Bayer AG internal research strength. Additional technical support facilities include Optical Media Laboratories in Pittsburgh and Baytown; a Film Insert Molding Center in Pittsburgh; and an Application Development Center, for styrenics research and development, in Springfield, Mass.

Bayer's Thermoplastic Product Families

- Makrolon® polycarbonate resins provide outstanding impact strength, superior dimensional stability, glass-like transparency, excellent thermal resistance and low-temperature toughness for applications in a broad range of markets, including automotive and transportation, building and construction, consumer products, electronics and telecommunications, medical[1] devices, optical lenses, packaging and photographic equipment. Bayer and its parent, Bayer AG, together constitute one of the world's leaders in supplying ultra-high purity resins for the compact disc and optical media markets.

- Apec® high-heat polycarbonate resins offer significantly higher heat resistance than standard polycarbonate resins, while retaining the excellent physical and optical characteristics of those resins. The resins are used for lenses and reflectors in automotive lighting devices, components for residential and industrial lighting systems, and for medical[1] devices and components.

- Makrofol® and Bayfol® polycarbonate and polycarbonate blend films are used in instrument panels, displays, membrane switches, control panels, nameplates, decals and other applications in the automotive, home appliance, computer, electrical/electronic, medical[1] device and packaging industries. Makrofol and Bayfol films are available for graphic arts and specialty film uses. A variety of surface textures can be supplied. A variety of specialty films are available offering special properties, such as excellent light-diffusing characteristics for automotive applications;

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